

## DEAR COLLEAGUE LETTER

### SMAP SCIENCE PRODUCT VALIDATION WITH IN SITU OBSERVATIONS

#### General Information:

Solicitation Number: NNH11ZDA008L  
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Response Date: March 1, 2011  
Classification Code: A -- Research and Development  
Issued by: Science Mission Directorate, NASA

#### 1. Scope of Program

No-cost responses (proposals) are solicited for participation in the calibration and validation (Cal/Val) program of the Soil Moisture Active-Passive (SMAP) mission through contributions that include *in situ* observations supporting SMAP mission products. This would be a partnership arrangement in which the partner provides SMAP with timely information for assessing mission performance and product quality. In return, SMAP will provide mission products to the partners during the SMAP Cal/Val phase, prior to general public release of the data, as well as over the entire mission life. Any responses selected for discussion could lead to a Memorandum of Agreement (MOA) or other partnership agreement on a no-exchange-of-costs basis only.

The SMAP validation effort is seeking sources of *in situ* data for validating the Level 2, 3, and 4 soil moisture, freeze-thaw, and carbon products. Specific areas of contribution include (listed in terms of the increasing value of the data set to the mission):

- Establishment of validation sites that are instrumented with *in situ* sensors for soil moisture and/or freeze/thaw monitoring. Sparse and dense networks can each play a role.
- Sites that satisfy most of the requirements for core sites as described in a later section.
- Provision of *in situ* data from these sites to the SMAP Science Data System (SDS) Cal/Val data archive in a timely manner relative to the SMAP Cal/Val schedule.
- Quality control of the *in situ* data, including referencing of the observations to standard techniques established by the Project.
- Analysis and provision of areal estimates of soil moisture, freeze/thaw state, and land-atmosphere CO<sub>2</sub> fluxes commensurate with the spatial and temporal scales of the SMAP data products.
- L-band measurements from aircraft/tower microwave instruments will also be considered, as long as they are obtained in conjunction with *in situ* measurements of geophysical parameters as described in Section 3.

This solicitation is open to all categories of respondents, including U.S. and non-U.S. groups and individuals. Having a diverse set of conditions and a broad geographic distribution of sites are critical to the success of the SMAP Cal/Val effort.

All selected respondents will be members of the SMAP Cal/Val Team. The selected proposed contributions will be incorporated into the final SMAP Cal/Val Plan. A memorandum of agreement will be established between NASA HQ, the SMAP project, and the selected response contributors. Cal/Val Team members will have access to versions of SMAP data products during the project Cal/Val phase (indicated in Figure 1) prior to general public release of these data. Team members will participate in the implementation of the SMAP Cal/Val Plan through meetings, workshops, and related activities.

## 2. The SMAP Mission

The SMAP mission will use both active (radar) and passive (radiometer) L-band microwave remote sensing to determine the near surface soil moisture and surface freeze/thaw state. The accuracy, resolution, and global coverage provided by SMAP measurements will serve science and application disciplines that include hydrology, climate, and the carbon cycle, and the meteorological, environmental, and ecological applications communities.

SMAP is identified as a first-tier mission in the National Research Council report “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond” ([http://www.nap.edu/catalog.php?record\\_id=11820](http://www.nap.edu/catalog.php?record_id=11820)), also referred to as the Earth Science Decadal Survey. Information on the SMAP mission and its capabilities can be found at <http://smap.jpl.nasa.gov/>. SMAP is currently targeted for launch in late 2014.

The baseline SMAP science data products that will be made available to the public are described in Table 1. These include sensor data (Level 1), retrieved geophysical data mapped to an Earth grid (orbit-based Level 2 and daily composited Level 3) and land model-assimilated data products (Level 4). In addition to these mission products, a research level radar-only 3-km resolution soil moisture product will be produced – support for its evaluation is needed.

Table 1. SMAP Mission Products

Data Product Short Name	Short Description	Spatial Resolution (km)	Grid Spacing (km)
L1A Radar	Radar raw data in time order	NA	NA
L1A Radiometer	Radiometer raw data in time order	NA	NA
L1B S0 LoRes	Low resolution radar $\sigma^0$ in time order	5x30	NA
L1B TB	Radiometer <i>TB</i> in time order	40	NA
L1C S0 HiRes	High resolution radar $\sigma^0$ (half orbit, gridded)	1x1 to 1x30	1
L1C TB	Radiometer <i>TB</i> (half orbit, gridded)	40	36
L2 SM P	Soil moisture (radiometer, half orbit)	40	36
L2 SM A/P	Soil moisture (radar/radiometer, half orbit)	9	9
L3 F/T A	Freeze/thaw state (radar, daily composite)	3	3
L3 SM P	Soil moisture (radiometer, daily composite)	40	36
L3 SM A/P	Soil moisture (radar/radiometer, daily composite)	9	9
L4 SM	Soil moisture (surface and root zone)	9	9
L4 C	Carbon net ecosystem exchange (NEE)	9	1
NA-Not applicable			

### 2.1. Postlaunch Cal/Val Timeline and Data Policy

Timeliness in providing validation data is a critical aspect of the Cal/Val program. The SMAP postlaunch timeline is shown in Figure 1. Current plans are for the SMAP observatory to complete an In-Orbit Checkout (IOC) period within 90 days after launch and then operate beyond the end of the IOC for a total science mission duration of three years.

Following the IOC period, the SMAP Project will complete an initial Cal/Val of the data products. It is required that beta (or provisional) versions of Level 1 and 2 products be released three months after completion of IOC. Subsequently, the validated data will be released six months after IOC for Level 1 products and 12 months after IOC for product Levels 2, 3, and 4. During the initial data Cal/Val phase, only Science Team members, Cal/Val Team members, and applications community Early Adopters will have access to data other than released versions.

At the conclusion of each product's Cal/Val period, calibrated and validated data from that period will be made available for public release through a NASA-designated archive (Data Center), and newly acquired data products will be released on a routine basis. The final and long-term archival data produced by the SMAP mission will be delivered to the public archive (Data Center) within six months after the end of the mission. Cal/Val will continue throughout the mission to monitor performance and assist in the improvement of algorithms.

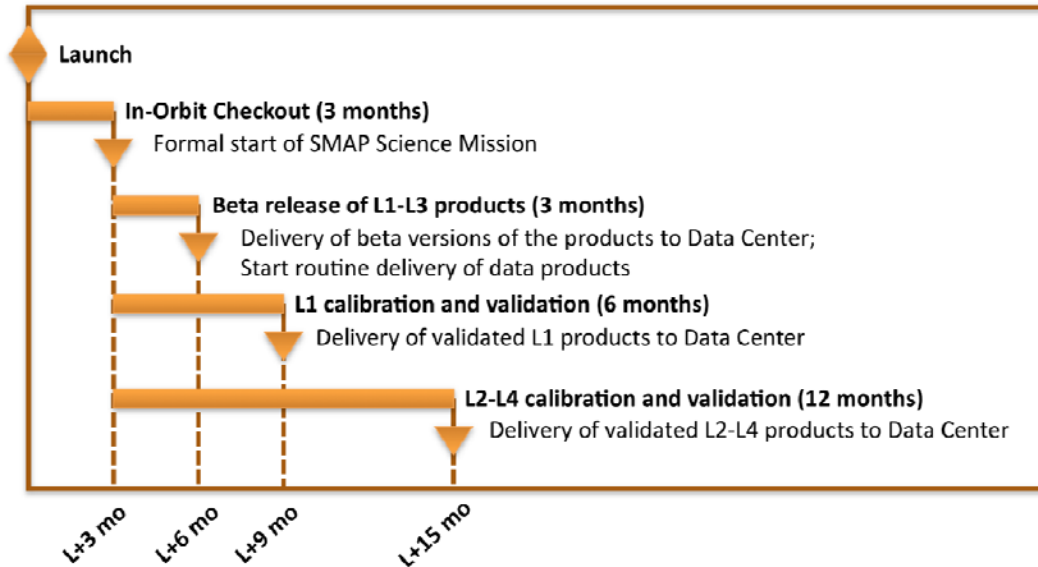


Figure 1. Timeline for SMAP Data Product Availability after Launch.

***It is critical to the SMAP Cal/Val effort that the postlaunch validation processes are fully implemented and ready to provide data prior to launch.*** All issues regarding *in situ* instrument installation, calibration, and scaling need to be addressed during the prelaunch period. As mentioned earlier, the data must be provided in a timely manner, ideally approaching real-time. The realities of establishing a supporting infrastructure and quality control of data may prevent some contributors from meeting this goal. Therefore, no more than a one-week time lag for the *in situ* sites is desirable for participation in the SMAP Cal/Val effort. As noted above, validation will continue beyond the Cal/Val phase. Data sources that might not meet the desired requirements may still be useful to the project in the longer term.

## 2.2. SMAP Cal/Val Plan

A SMAP Cal/Val Plan has been developed that describes the approach to be used in assessing the quality and accuracy of the SMAP data products, to improve the retrieval algorithms, and to provide a final validated mission data set that meets the mission requirements. A copy of the preliminary Cal/Val Plan is available at <http://smap.jpl.nasa.gov/science/Validation/>.

The SMAP Cal/Val Plan includes both prelaunch and postlaunch activities:

- Prelaunch objectives are to:
  - Acquire and process data with which to calibrate, test, and improve models and algorithms used for retrieving SMAP science data products;
  - Develop and test techniques and protocols used to acquire validation data and to validate SMAP science products in the postlaunch phase.
- Postlaunch objectives are to:
  - Verify and improve the performance of the science algorithms;
  - Validate the accuracy of the science data products.

Ground-based or *in situ* observations are one of the resources that will be employed in validation. Establishing, calibrating, and maintaining a robust and globally distributed network of *in situ* instrumentation will be essential to the success of the SMAP Cal/Val program. Recognizing the breadth of issues involved in acquiring these data, the SMAP project will attempt to achieve its objective through partnerships with complementary operational and research programs around the globe. *In situ* soil moisture, surface and air temperature, CO<sub>2</sub> flux and land surface characteristics observations will be important in validating the SMAP L2 and higher-level science products. In addition, aircraft and/or tower-based L-band microwave measurements taken as part of an ongoing measurement program at these *in situ* sites are welcome, especially data from instrument systems currently deployed in support of SMOS.

In addition to the postlaunch Cal/Val activities, if the networks are available sooner, these *in situ* data will be valuable throughout the development phase of the mission to support field campaigns, modeling, and synergistic studies using sensors on the Aqua, ALOS, SMOS, and Aquarius platforms to simulate SMAP products. *Therefore, the desired time span of in situ observations, based on current SMAP launch projections, is 2012-2017.* To meet this requirement, these networks must establish some level of long term commitment from their sponsors.

### 2.3. SMAP Science Requirements

In order to better understand what is required of the desired *in situ* resources, the following information on the SMAP baseline science requirements is provided. These include accuracy, spatial resolution, and temporal revisit for the soil moisture and freeze/thaw measurements, as well as mission duration. These are summarized below and in Table 2:

- *Provide estimates of soil moisture in the top 5 cm of soil with an error no greater than 0.04 m<sup>3</sup>/m<sup>3</sup> volumetric (one sigma) at a 9 km spatial resolution and at intervals of 3 days (over the global land area excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 kg/m<sup>2</sup> (averaged over the spatial resolution scale))*
- *Provide estimates of surface binary freeze/thaw state with a classification accuracy of 80% at 3 km spatial resolution and 2-day average intervals in the region north of 45N latitude which includes the boreal forest zone.*
- *Collect the space-based measurements needed to retrieve estimates of soil moisture and freeze/thaw state for at least three years to enable the natural seasonal variations of soil moisture and freeze/thaw and their impacts on the surface energy, water, and carbon balances to be characterized.*

The SMAP Cal/Val program will assess whether the SMAP retrievals of soil moisture and freeze/thaw state meet the stated science requirements. Beyond the Science Measurement Requirements noted above, each product listed in Table 1 must be validated (note that this request only considers Levels 2 and higher products). Although the accuracy requirements stated for the freeze-thaw classification are for the region north of 45N latitude, SMAP will deliver a global-scale freeze-thaw product.

Table 2. SMAP Level 1 Science Measurement Requirements

	Baseline Mission		Minimum Mission	
	Soil Moisture	Freeze/Thaw	Soil Moisture	Freeze/Thaw
Resolution	10 km	3 km	10 km	10 km
Refresh Rate	3 days	2 days	3 days	3 days
Accuracy	0.04 m <sup>3</sup> /m <sup>3</sup>	80%	0.06 m <sup>3</sup> /m <sup>3</sup>	70%

### 3. SMAP Product Validation

Validation is the process of assessing by independent means the uncertainties of the data products derived from the system outputs. This is also compatible with the validation definition by the Committee on Earth Observing Satellites (CEOS):

[http://www.ceos.org/index.php?option=com\\_content&view=category&layout=blog&id=75&Itemid=116](http://www.ceos.org/index.php?option=com_content&view=category&layout=blog&id=75&Itemid=116).

A valuable lesson learned in global land imaging has been that validation is critical for accurate and credible product usage. It must be based on quantitative estimates of uncertainty for all products. For satellite-based retrievals, this should include direct comparison with independent correlative measurements. The assessment of uncertainty must also be conducted and presented to the community in normally used metrics in order to facilitate acceptance and implementation.

Another important consideration for SMAP Cal/Val implementation (which will utilize data from a variety of observing programs with varying objectives) is establishing global consistency in the correlative data. Almost every *in situ* resource has some variation in its instrumentation and design that must be taken into consideration. *Therefore, each response must describe in detail what will be provided and how the measurements will be related to the SMAP product suite.* Additional details for soil moisture, freeze-thaw, and Net Ecosystem CO<sub>2</sub> Exchange (NEE) related responses are provided in a following section.

The SMAP validation will follow an approach similar to the guidelines of CEOS Cal/Val Land Products Group (<http://lpvs.gsfc.nasa.gov/>), which envisions validation as an evolving process. Within this approach, there are roles for sparse networks over extensive domains, as well as more intensive observations over individual product grids.

SMAP will provide global products. Therefore, product validation should be representative of a wide range of global climate and vegetation conditions. Logistics and potential costs will require partnerships that leverage ongoing programs, both within the U.S. and internationally. *Each response should describe the infrastructure and anticipated support of the program.*

#### 3.1. Specific Considerations for Soil Moisture (L2 -L4)

*In situ* methods provide point observations and each point is orders of magnitude different from satellite grid products. A variety of techniques can be used to establish the scaling of the points

and grids. Although it is not a requirement for participation, each response should describe what methods will be used if they choose to scale their measurements up to a SMAP grid cell.

*In situ* measurement and scaling of soil moisture presents many challenges. As a result, there are a wide range of measurement techniques that have been adopted in practice. Each of these can involve different issues in calibration and installation. The value of these measurements to SMAP validation will depend upon (1) the quality of the measurements, (2) how they can be related to the other global *in situ* resources that SMAP will employ, and (3) how the measurement relates to the validation criteria (in particular the depths and scales). *In order to facilitate satisfying item (2), it is requested that the measurements from a particular site be calibrated using the thermogravimetric method (Chapter 3.1.2.1 in Dane and Topp, 2002<sup>1</sup>)* – this is commonly referred to as the gravimetric sampling method. The specific approach that will be used by the proposer should be described. If the response includes microwave measurements, as well as *in situ* geophysical measurements, an estimation of the calibration accuracy of the microwave measurements should be included, as well as a description of the method used to obtain this estimate.

Item (3) must also be addressed in the response. The various measurement techniques and installation approaches involve variations in the sensor integrating depth and area. The measurement depth criteria for SMAP is 0-5 cm for L2 / L3 validation and 0-100 cm for L4 validation.

#### 3.1.1. Recommended calibration of *in situ* soil moisture measurements using gravimetric sampling for the surface layer

All sensor systems must provide an estimate of the volumetric soil moisture in the surface 5 cm depth of the soil. This involves at least two steps: 1) establishing that the sensor provides the equivalent of the volumetric soil moisture that would be obtained by gravimetric sampling, and 2) if the sensor does not actually measure the 0-5 cm layer, providing verification that the sensor values are well correlated to a 0-5 cm measurement.

The most straightforward way to provide both items above is to sample the 0-5 cm soil layer using a volume extraction method, such as a ring coring tool. The ring is a known volume (cm<sup>3</sup>). Soil in the ring is weighed, dried, and weighed again to obtain the mass of water (gm) in the known volume. With a specific density of 1 cm<sup>3</sup>/gm for water, the result is the volumetric soil moisture (cm<sup>3</sup>/cm<sup>3</sup>). The more replications obtained near the sensor, the more reliable will be the calibration. It is also necessary to repeat the procedure at several different levels of soil moisture.

An alternative to the method described above is to rely on laboratory calibration of the sensors. This can be done separately for each individual sensor or, if the device is highly reliable, once for all sensors. A problem with this approach is that variations in soil properties, which are known to influence calibrations, must be incorporated using additional ancillary information. It also does not account for site specific installation or referencing to the 0-5 cm layer.

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<sup>1</sup> Dane, J. H. and Topp, G. C. (ed.), Methods of Soil Analysis Part 4 Physical Methods, Soil Science Society of America, Madison, WI, 2002.

### 3.2. Specific Considerations for Freeze/Thaw (L3\_FT)

*In situ* frozen/nonfrozen status will be determined as a composite ensemble of vegetation, soil and air temperature measurements where available, and will be compared to coincident footprint scale L3 freeze/thaw measurements for areas of the globe where seasonally frozen temperatures are a major constraint to hydrological and ecosystem processes. The fulfillment of the requirements will be assessed by comparing SMAP freeze-thaw classification results and *in situ* frozen or nonfrozen status. The resolution of the L3\_FT product is 3 km. The *in situ* measurements will need to be upscaled to a similar spatial scale for validation purposes. The *in situ* resource should provide a strategy for spatial upscaling of *in situ* measurements commensurate with the 3 km spatial scale of the satellite retrieval, if they intend to provide this information. Attention should be given to landscape heterogeneity within the scope of the validation site or sites in the upscaling strategy.

#### 3.2.1. Recommendations for freeze/thaw *in situ* core site measurements

Measurements supporting freeze-thaw Cal/Val activities should meet the following minimum requirements:

- Measurement of surface (screen height) air temperature
- Measurement of surface (up to 10 cm depth) and profile (up to 1 m depth) soil temperatures
- Measurement of vegetation temperature (when significant vegetation is present)
- *In situ* temperature measurements should be sufficient to characterize the variability in local microclimate heterogeneity within a spatial scale compatible with the SMAP freeze-thaw product
- To provide uniformity across sites, the local land cover of the site should be consistent with a global (IGBP-type) land cover classification
- Each land cover class within the validation site should be captured within the suite of temperature measurements such that the local vegetation and land cover heterogeneity is represented
- Measurements should have sufficient temporal fidelity to capture seasonal and diurnal temperature and freeze-thaw patterns

Desired methods for measuring air, soil, and vegetation temperatures include thermocouple type measures of physical temperatures and thermal IR type measurements of surface “skin” temperatures with consistent and well documented accuracy and error sources over a large (e.g. -30°C to 40°C) temperature range.

### 3.3. Specific Considerations for NEE product (L4\_C)

The accuracy of the L4\_C outputs, including NEE and component carbon fluxes will be established in relation to *in situ* tower eddy flux CO<sub>2</sub> measurements and associated carbon budgets within regionally dominant vegetation classes following established protocols. The

fulfillment of the NEE requirement will be assessed by comparing SMAP L4\_C NEE output with *in situ* measurement-based CO<sub>2</sub> flux estimates.

In order for a flux tower to be useful for NEE validation, it has to provide, at a minimum, the following measurements:

- Continuous daily (cumulative 24-hr) estimates of gross primary production (GPP), ecosystem respiration ( $R_{eco}$ ), and NEE with well defined and documented accuracy, including both systematic and random errors;
- Relatively homogeneous land cover and vegetation conditions within an approximate 10 km x 10 km footprint commensurate with the resolution of the SMAP L4\_C product;
- To provide uniformity across sites, the local land cover of the site should be compatible with a global (IGBP-type) land cover classification;
- The local site should have a minimum level of supporting meteorological measurements, including air temperature and humidity, surface ( $\leq 10$  cm depth) soil moisture and soil temperature, precipitation, and snow depth (if present); these measurements should be continuously monitored and sufficient to capture local microclimate heterogeneity within the tower footprint;
- The local site should have a minimum level of supporting biophysical inventory measurements, including surface ( $\leq 10$  cm depth) soil organic carbon stocks, vegetation stand age class, land use, and disturbance history.

### 3.4. Core Validation Sites

The highest priority *in situ* resources for SMAP Cal/Val are Core Validation sites. The scientific objective of these sites is to provide *in situ* observations that can be used to estimate soil moisture and/or freeze thaw accurately at the spatial resolution of the SMAP geophysical data products, while satisfying all the other requirements described in previous sections. An essential requirement is that the design includes multiple locations within a site that would provide a statistically reliable estimate. Furthermore, estimates of ground-truth sampling error must accompany the product area mean values.

These sites would be the focus of intensive ground and aircraft field campaigns to further verify scaling. Extensive ancillary data sets would be established to support algorithm development and implementation at multiple scales and water, energy, and carbon models and other synergistic science. Core sites have been an important component of previous efforts to use remote sensing to estimate soil moisture (AMSR-E, SMOS) and other land parameters. Of particular interest are ongoing Cal/Val efforts and *in situ* data acquisitions of other ongoing missions (AMSR and SMOS) that approximate the Core site requirements.

The following minimum criteria are desired for a Core validation site:

- Accessible to researchers
- Has existing infrastructure, including access and utilities
- Heritage of scientific studies to build from
- Long term commitment by the sponsor/host
- An area that is homogeneous or has a uniform mixture of land covers at the product scale

- Represents an extensive or important biome
- Complements the overall set of sites

For soil moisture it is also suggested that a Core site have a minimum of nine points for each grid cell. Each Core site should include, at a minimum, two 3 km cells and two 9 km cells within a 36 km cell.

#### 4. Requested Information

Responses should consist of no more than 10 pages and include responses to the items described above, specifically:

- The measurements that will be provided (sensor type; installation details including orientation and depths; frequency of measurement, including integration period; number of sites; locations including a map with a scale; etc.)
- Data latency
- Methods that will be used for sensor calibration
- Methods that will be used for sensor scaling, if applicable
- Infrastructure and anticipated support of the program
- How and when observations will be supplied to the SMAP Project
- For soil moisture, the approach that will be used to cross reference the measurements to volumetric soil moisture in the specified depths as determined by the gravimetric method.

Responses will be evaluated on the basis of the proven capabilities of the principal investigators, the approaches and activities proposed to address the requirements described here, the maturity, infrastructure, and long-term support of the *in situ* resources, and the perceived value of the proposed site(s) to the SMAP Project.

#### 5. Instructions

All responses submitted in response to this Dear Colleague Letter must be submitted in electronic form via NSPIRES, the NASA online announcement data management system, located at <http://nspires.nasaprs.com/>. For this Letter, a response submission will take the form of a Notice of Intent (NOI) within the NSPIRES online announcement data management system. The response itself will be a PDF-formatted document that is attached (uploaded) to the NSPIRES system.

The deadline for responses is March 1, 2011.

You must be registered with NSPIRES to submit a response. See registration instructions at <http://nspires.nasaprs.com/> (select “Getting an account”). Neither institution registration nor an institution affiliation is required to respond to this Dear Colleague Letter.

1. Log in to your account at <http://nspires.nasaprs.com/>.
2. Select “Proposals” from your account page.
3. Select “Create NOI” from your proposals page.
4. Click “Continue” on the next page.

5. Select “Dear Colleague Letter: NNH11ZDA008L (SMAP Science Product Validation With In Situ Observations)” from the bullet list of announcements. Click “Continue”.
6. Enter response title (“NOI title” field will be shown).
7. Select “do not link at this time” for submitting organization page.
8. Click “Save” on next page.
9. It is not necessary to complete any of the “NOI Details”; all requested information must be included in the attached PDF document. Information which is entered into “NOI Details” but not included in the attached PDF document will not be considered.
10. Prepare your response offline and save as a PDF document (note NSPIRES instructions on .pdf formats). The response document must include the respondent’s name, institution, phone number, and E-mail address so the file is self-contained. File names format should be “Respondent Last Name - First Name - SMAP”. The response should not exceed 10 pages in length.
11. To attach (upload) your PDF document:
  - a. Click “add” under NOI attachments section;
  - b. Select “Proposal Document” from the drop down list;
  - c. Browse to attach your PDF file;
  - d. Select “Upload”;
  - e. Click “OK”;
  - f. Your response document has been uploaded to NSPIRES.
12. Click “Submit NOI” button. NOTE that this does not complete the submission process.
13. Ignore any warnings about incomplete NOI elements. Ensure that your response (NOI) document is attached and click “Continue”.
14. Click “Submit”. This will take you to the NOI submission confirmation page, which provides you with the NOI/response number for your records.

Please note: You may delete and replace form fields and uploaded documents anytime before the submission deadline. Submitted NOIs cannot be deleted.

## 6. NASA Point of Contact

For further information on this Dear Colleague Letter, please contact Dr. Jared K. Entin, Science Mission Directorate, Earth Science Division, NASA Headquarters, 300 E Street SW, Washington, DC 20546; Telephone (202) 358-0275; E-mail [Jared.K.Entin@nasa.gov](mailto:Jared.K.Entin@nasa.gov).